THE POSSIBLE GRANITIZATION OF ACIDIC LOWER HURONIAN SCHISTS ON THE NORTH SHORE OF LAKE SUPERIOR

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The Michipicoten and Pucaswa areas on the north shore of Lake Superior present the apparently extraordinary anomaly of containing a conglomerate well supplied with characteristic granitic pebbles, and of exhibiting no older granitic rock of similar structure from which these pebbles could have been drawn. There are, however, of earlier age, acid schists and gneisses of probable igneous origin, and apparently of like chemical composition, though of different structure from these granitic rocks. I would suggest the possibility of the derivation of the granitic pebbles in the conglomerate from a preexisting rock of like characteristics, of which the granite which cuts the conglomerate is the regranitized equivalent. By a regranitized rock I mean one which, originally a granite, quartz-porphyry, or other rock of similar chemical composition and origin, has by metamorphism been altered into an acid gneiss or schist, and subsequent to the metamorphism—or perhaps in part during the metamorphism—recrystallized back into a granite. From our present knowledge of the origin of granite, this recrystallization cannot definitely be said to be refusion, and regranitization is perhaps a more correct and exact term. The original granite, the source of the granitic pebbles, may have been the plutonic equivalent of the rock from which the acid gneisses and quartz-porphyry or felsite schists were derived. It is possible that the gneisses may represent the metamorphic remnant of the original granite.

The Michipicoten Mining Division, which contains an area of some 5,000 square miles, is part of the District of Algoma, in Ontario, and is situated on the northeastern shore of Lake Superior, between latitudes 47° 30′ and 48° 30′. The division was first set apart by the government of the province of Ontario on account of the aurifer-

ous quartz veins which it contains, though it has within the last few years become more important as an iron-ore producer. One mine—the Helen—exports more ore annually than all the other iron mines in Canada put together. Lying within the boundaries of the division is the Michipicoten Huronian area, and to the southwest of the division, and in part within it, is the Pucaswa Huronian area, separated from the Michipicoten area by granite of later age than either.

The Michipicoten Huronian rocks constitute a band from four to twelve miles in width, which extends northward from a point a few miles south of Point Gargantua, on the Lake Superior Shore, to a point about 14 miles south of the main line of the Canadian Pacific Railway. From this point an arm extends both east and west. The western arm, which is the longest and most important, stretches westward from the Magpie River, which may be taken as the center of the north-and-south arm, for a distance of about 40 miles, where it is cut off by granitic rocks. The eastern arm extends eastward from the Magpie River for about 25 miles, and is intercepted by granitic rocks in the neighborhood of Dog Lake. South and southwest of the western arm lie small patches of Huronian rocks which compose the Pucaswa area. The Pucaswa[1] area would naturally be included within the Michipicoten area, because of the similarity in the lithology of each and on account of their proximity, were it not that the Pucaswa Iron Range is quite separate and distinct from the Michipicoten Iron Range in geographical position, and differs markedly in structural features.

The boundaries of the Huronian rock in both the Michipicoten and Pucaswa areas are extremely irregular, but everywhere the bordering rocks are composed of granite or rocks of allied petrographic species. The outer boundary is formed by granitic rocks which are apparently part of the great Laurentian acid eruptive complex of central Canada, which extends northward to within 60 miles of Hudson Bay, and southeastward to the original Huronian area of Logan and Murray—a distance of 120 miles. The inner boundary of the Michipicoten area is an immense granitic batholith with principal dimensions of 19 miles from north to south by 28 miles

[1] In the paper by the writer in the Bureau of Mines *Report* for 1905 the Pucaswa area is called the North Michipicoten area.

from east to west. This batholith is joined to the main part of the acid eruptive complex by a narrow band of granite, which separates the Michipicoten Huronian area from the Pucaswa Huronian area. Another off-shoot from the batholith further divides the Pucaswa area.

The oldest rocks visible in both the Pucaswa and the Michipicoten areas are the so-called Lower Huronian. Above these lie Upper Huronian rocks which, though somewhat rare in the Pucaswa area, have abundant outcrops in the Michipicoten area. Cutting both Lower and Upper Huronian are granites and allied rocks, which have frequent outcrops in the shape of bosses and dykes, within the limits of the Huronian rocks proper, and which have also already been mentioned as forming the boundaries of the Pucaswa and Michipicoten areas. Piercing both the Huronian rocks and the granites are basic igneous rocks of somewhat varied lithological composition, which are very probably Keweenawan.

The Michipicoten Lower Huronian may be subdivided into two divisions—the Helen Iron Formation and the Michipicoten schists. The same rocks in the Pucaswa area may be similarly resolved into an Iron Formation and schists. The Iron Formation in the Michipicoten area and in the Pucaswa area may be regarded as the only definite horizons within the Lower Huronian of the areas. Above and below these formations lie the schists. In the Michipicoten area, and particularly in that part which lies west of the Magpie River, a very close connection between the Upper Huronian rocks and the Helen Formation is observable. The latter, generally, very closely underlies the Doré Formation which in Michipicoten makes up the Upper Huronian, but in some parts of the area thick masses of schists intervene between the Helen Formation and the Doré Formation, indicating either an unequal denudation of the Lower Huronian previous to the deposition of the Doré rocks, or otherwise an unequal deposition of volcanic material after the Helen iron-bearing rocks have been laid down. In some places the width of the Helen rocks appears to diminish, and at the same time there is a relative increase in the amount of schist which seems to suggest that in these parts of the area, toward the close of Lower Huronian times, chemical and aqueous sedimentation was overpowered by volcanic

deposition, whereas elsewhere the former still continued. In the Pucaswa area no such close relation between the iron formation and the Upper Huronian is apparent.

The rocks of the Helen Formation consist of rusty, ferruginous, banded cherts, banded jaspers, banded magnetic cherts, pyritic cherts, sideritic cherts, and various grüneritic, actinolitic, and hornblendic schists, resulting from their metamorphism, together with phyllites, sideritic arkoses, and possibly quartzites. The Iron Formation in the Pucaswa area consists of similar rocks, though sideritic cherts are rare or wanting, and magnetic, banded chert is the most common iron-bearing rock, whereas in the Michipicoten area rusty, non-magnetic, banded chert is the prevailing species.

The schists of both areas comprise chloritic schists, mica schists, hornblende schists, carbonate schists, quartz-porphyry and felsite schists, schistose agglomerates, and amphibolites. All of the schists are intensely sheared, and some of them, particularly the finer-grained varieties, are so evenly laminated that they very closely resemble, and probably actually are, phyllites. Quartz-porphyry schist, a nacreous sericitic rock containing blebs of glassy quartz and sometimes gneissoid, very frequently borders the iron formation in the Michipicoten area, and carbonate schists are also often in close connection. Apart from this somewhat general definite position occupied by these two schists, no exact horizons are held by any other of the Lower Huronian schists.

The Upper Huronian in the Michipicoten and Pucaswa areas consists of the Doré Formation, comprising conglomerates, agglomerates, slates, and tuffs—the conglomerates being the commonest, most significant, and most characteristic. The Doré conglomerate is a very much mashed rock, with a fine-grained chloritic matrix, containing within it rounded fragments of pre-existing rocks of all sizes, from those scarcely visible to the eye, to others a foot or more in diameter. The ground-mass is exceedingly schistose, and the cobbles and pebbles included in it are all more or less elongated parallel to this structure. The harder pebbles show only flattening, parallel to the longer diameter, while the softer pebbles are often so attenuated that they resemble long narrow ribbons, or else are so thoroughly comminuted as to be indistinguishable from the matrix proper. The

pebbles are of granite, quartz-porphyry, felspar-porphyry, felsite, of various cherty rocks derived from the iron formations of the Lower Huronian and of schists and phyllites. Of these perhaps those which stand out most prominently, and which are of most general occurrence, are of the granite rocks, and more especially of a light-colored grayish or pinkish and somewhat porphyritic granite. Sometimes pebbles are almost or entirely wanting, and then the conglomerate passes into the Doré slate—a somewhat rare phase of the Doré Formation, but occurring at several points, notably at the mouth of the Dog River. The Doré agglomerate is also rare, but occurs prominently at several points in the northern part of Michipicoten. It is a somewhat fine-grained chloritic or sericitic rock, containing sometimes a great many, but generally a very few, fragments of rocks, usually of the same chemical composition as the ground-mass, but more coarse-grained, and very frequently porphyritic. It is occasionally with difficulty distinguishable from the water-formed rock. When without fragments it becomes the Doré tuff—a form in general of very unusual occurrence.

The Post-Huronian acid eruptives consist of granites, felsites, syenites, and acid porphyries. Excepting toward the contact with other formations, the porphyritic or felsitic phase is rare, and by far the commonest species, both in the smaller bosses and in the main masses, consists of an even and medium-grained granite of light pinkish color. Though always weathered, it is often remarkably fresh considering its antiquity. It is a much-sheared igneous rock, but not so intensely so as are the igneous rocks which form so prominent a part of the Lower Huronian schists.

That these acid eruptives cut the Huronian rocks all along the line of contact, and are hence later than these rocks, seems almost undoubted, and though outcrops are often poor, owing to the quantity of drift or the thickness of vegetation, still the eruptive contact of the granite with the Huronian rocks is excellently shown in many places. In the compass of this paper no detailed account of many interesting contacts between the Huronian and the granitic rocks can be given. Several representative instances may, however, be cited. Very many points of contact were seen in which the irruptive nature of the granite into the Lower Huronian schists is apparent. Perhaps

the most interesting observed is that seen north of Lake Charlotte, an irregular sheet of water about two miles long, lying within an embayment in granitic rocks just north of Kabenung Lake, and within a few miles of the Dog River. The rocks exposed along the cliffs which flank the northern shore of the lake consist of rusty and sometimes banded cherts, with quartz-magnetite, hornblendic schists and epidote schists, which represent metamorphosed Helen Rocks and Michipicoten schists. A short distance north from the shore, and interstratified with the metamorphic schists, are narrow bands of a light-colored felsite and of coarse-grained quartz-porphyry. Northward from the lake shore these sheets of acid igneous rock increase in width, become more granitic, and are of more frequent occurrence. Moreover, they are often joined one to the other by narrow apophyses of similar rocks. About one half-mile north from the lake granites alone are seen, though occasional small inclusions of schist are of somewhat common occurrence within them, especially close to the contact. Immediately south of the "final contact" the schists are so much metamorphosed that they consist almost entirely of epidote and similar metamorphic minerals, or else are so dense and fine-grained that they are indistinguishable from a hornfels. The granite is of the usual medium-grained, light-pinkish type, and, though distinctly sheared, is not perceptibly laminated, and so could hardly be called gneiss. This granite is apparently part of the great area of acid igneous rocks which stretches northward to within a few miles of Hudson Bay.

An excellent contact between the granitic rocks and the Helen Formation is shown at Mount Raymond, one of the most prominent hills in the Michipicoten area, and which lies just west of Paint Lake and within a mile of the Frances Mine. At this point the Helen Formation is cut by a wide dyke of porphyritic granitic rocks, which forms the most prominent part of Mount Raymond. The iron-bearing rocks are metamorphosed into actinolitic and grüneritic magnetite schists. Contact deposits of impure magnetite occur close to the border of the dyke, and a wide vein of quartz, which is decidedly pyritous and slightly auriferous, has developed within the adjoining rocks. Compared with the intense metamorphic effect exerted by this granite, the decided lack of visible metamorphic

influence generally exercised by the granite, cutting the iron formation in the Pucaswa area, stands in very marked contrast. For instance, the iron formation there is intruded by a huge granitic batholith on the eastern branch of the Pucaswa River, about four miles above its confluence with the western branch. The eruptive contact is abrupt and decided, but the iron formation, which consists of banded magnetic chert, is relatively practically unaltered. The granite is bright red and somewhat coarse-grained, though of even texture.

Visible contacts between the Upper Huronian and the intruding granites are rare as compared with those with the Lower Huronian. This is due probably to the much smaller surface area occupied by the Upper Huronian rocks. There is a good contact showing distinctly the eruptive relations of the granite on the southern shore of Lake Charlotte. Another is on the western shore of Western Lake Kabenung, and still another, and one which is perhaps better shown than either of the others just given, on the shore of Lake Superior, near the mouth of the Doré River.

Somewhat interesting is the geologic section exhibited along the Lake Superior shore from Otter Head eastward. Here the ceaseless washing of the waters has kept the rocks well exposed, and the relations existing between the different formations is easily observed. At Otter Head the rocks, named in order of their age, consist of small areas of evenly banded gneiss, ordinary light-reddish granite, coarse-grained pegmatite, quartz and calcite veins, and dykes of basic igneous rocks. The gneiss is composed of alternating bands one-quarter of an inch and less in width, of dark-colored minerals, chiefly biotite, and similar bands of light-colored minerals, chiefly orthoclase, oligoclase, and quartz. There is apparently not much differentiation into laminæ of the felspar minerals and quartz. The light-reddish granite, which is the prevailing rock, is exactly similar to the Post-Huronian granite described above. The pegmatite, consisting chiefly of large individuals of microcline, orthoclase, plagioclase, quartz, and biotite was probably formed as the result of the action of steam acting upon the hot granitic magma, either during or immediately following its intrusion. The veins are later than either granite or pegmatite, but probably owe their origin to the circulating thermal waters, which followed, and were the result of, the granitic intrusion.

Eastward from Otter Head the inclusions of gneiss appear of finer grain, though always very evenly banded. Gradually these inclusions become more and more common and widen into definite bands, alternating with areas of granite, and more closely resemble the ordinary types of schist. Sometimes the bands of schist are joined to each other by strips of granite. Finally, at about nine miles east of Otter Head, at the prominent point just east of Richardson's Harbour and about four miles west of the mouth of the Pucaswa River, schists alone appear, and are the prevailing rock as far as Ganley's Harbour.

Now, the points which I wish to emphasize are these:

1. A prominent part of the Lower Huronian schists is composed of felsite and quartz-porphyry schists which have sometimes a gneissoid appearance.

2. An Upper Huronian conglomerate contains many granite, quartz-porphyry, and felsite pebbles which are unlike the Post-Huronian acid eruptive rocks. The pebbles of quartz-porphyry and of felsite were probably derived from flows of quartz-porphyry and felsite, now represented by their metamorphic equivalents, the quartz-porphyry and felsite schists. No rock earlier than the conglomerate at present outcrops from which the granite pebbles could have been derived, unless it is the acid gneiss.

3. Immense masses of granites and other acid eruptives cut the Huronian, and are hence later than these rocks. These granites form at least a very prominent part of the acid-eruptive complex, known as Laurentian. Contained as inclusions, sometimes of considerable size, within these acid eruptives, are earlier acid igneous rocks which are typical gneisses.

May not the areas of gneiss be of the same age as the Lower Huronian, and represent merely an intensely metamorphosed felsite or quartz-porphyry, or the deep-seated equivalent of these rocks? Again, is it not possible that the granite pebbles which occur in the Doré conglomerate were derived from a rock no longer existing, but of which the Post-Huronian granite is possibly the regranitized equivalent? Of this Pre-Upper-Huronian rock it is possible that the small patches of gneiss within the Post-Huronian granites are the metamorphosed remnant.

My reasons for thinking that the gneiss areas within the Post-Huronian eruptives are of the same age as the Lower Huronian schists and not earlier (as was the original idea of Sir William Logan and the earlier Canadian geologists) is perhaps a negative one, namely: there is absolutely no evidence of an unconformity between the gneisses and the schists.[1]

Of course, the gneiss may not be, as I suggest, a highly metamorphosed granite, or rock of similar lithological composition and origin. It may be a metamorphosed aluminous sediment, but, judging from the extreme rarity of rocks of such character in the Lower Huronian, this hardly seems likely, though dynamic agencies competent to cause regranitization of Lower Huronian acid eruptives may with considerable justice be considered capable of utterly destroying the identity of water-laid sediments.

Since there are no granites now outcropping similar to those exhibited by certain of the pebbles of the Doré conglomerate, it stands to reason that the granite from which they were derived must either be entirely covered by more recent rocks, or else have altered its state. The former hardly seems likely, because the area is large, and the granite pebbles of this particular sort occur everywhere within the Doré conglomerate. In favor of the second hypothesis—namely, a change of state—it may be said that wherever gneiss and granite areas occur together (which is very frequently the case) there seems to be some slight evidence that the latter is derived from the former. The evidence consists in a peculiar ragged, though sometimes gradual, transitional contact and in the numerous dykelets of granite which ramify through the smaller inclusions of gneiss. It may be objected that this contact is simply one characteristic of any eruptive contact between granite and gneiss. It is of course not my contention that the contact is not an eruptive one, but simply that the granite may be derived from the gneiss. A somewhat homely illustration of a similar phenomenon in nature to that of regranitization may be observed in the recrystallization of ice so frequently seen on the surface of a glacier. Here one may often find a very much banded mass of ice—the banding being due to compression—

[1] According to the International Committee, these schists would be called Kee watin. It will be seen that the geology as sketched in this paper is slightly different from that given by the committee.

veined and slashed with irregular and lensoid areas of more coarsely crystallized ice which show no banding, and represent small crevasses or irregular holes filled with water derived from the melting of the banded ice, and subsequently frozen. What little has been done by the writer seems, however, to prove the hypothesis. It is chiefly in the hope that microscopic and chemical work will be undertaken on this interesting problem, in a careful and systematic way, that these suggestions are now made.

If the theory which is here proposed with regard to the origin of the granites is correct, the geological history of the Michipicoten and Pucaswa areas may be briefly summed up as follows: First, were laid down the series of acid and basic volcanics, with the sedimentary phyllites and iron-bearing cherts, which compose the Lower Huronian on some pre-existing floor, of whatever character that may have been. These were gently folded, and in the consequent synclines were deposited the conglomerates and slates of the Doré Formation. Evidently volcanic activity continued during Upper Huronian times, allowing the deposition of the Doré agglomerates and tuffs. Succeeding the laying down of the Upper Huronian, both Upper and Lower Huronian rocks were intensely corrugated. During this corrugation, and in the main as the direct result of it, came the regranitization of the Lower Huronian acid igneous rocks, which must have existed in quantities largely predominating over all other rocks, and the consequent intrusion of vast masses of granites and allied rocks.